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Sentinel Surveys 1995-2016 – Catch rates and biological information on Atlantic Cod *(Gadus morhua)* in NAFO Subdivision 3Ps

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Catch rates and biological information for Atlantic Cod from the Sentinel Survey Program in the Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps are updated for 2016, and preliminary results presented for 2017. Temporal trends in gillnet (small 3¼ inch mesh, large 5½ inch mesh) and linetrawl unstandardized catch rates were similar for all gears, with the highest values at the beginning of each time-series, sharp declines after 1997, and oscillations around or below the series' mean catch rate thereafter. Mean catch rate for small mesh gillnets was consistently higher than that of large mesh gillnets for the entire time-series: peaking at 142 fish per net in 1996, and then averaging 11-36 fish/net; except for its lowest value of 6 fish/net in 2011. Large mesh gillnets yielded the lowest mean catch rate of all gears: declining from 49 fish/net in 1997 to less than 9 fish/net since 2000. Mean catch rate for linetrawls peaked at 223 fish per 1,000 hooks in 1996, and fluctuated around 100 fish/1,000 hooks until 2010 (except in 2006); prior to reaching its lowest value of 62 fish/1,000 hooks in 2014-2015. Sentinel catch rates for large mesh gillnet and linetrawl "control" locations were standardized using Generalized Linear Models. Age-disaggregated standardized catch rates for recent year-classes were generally weaker than those in the past; although proportions-at-age of large mesh gillnet catch rates suggested that the 2008 year-class was relatively stronger. Age-aggregated catch rates were higher at the beginning of each time-series for both gears, declined over the mid-to-late 1990s, then remained at their lowest levels; decreasing below the series' mean of 6.4 fish/net (large mesh gillnets) in 1999, and 86 fish/1,000 hooks in 2009 (linetrawls). Gillnet and linetrawl catch rates for 2016 were 1.5 fish/net and 57.5 fish/1,000 hooks, respectively.

Length frequencies of Atlantic Cod measured in Sentinel Surveys indicated that the small mesh gillnet was the least selective gear (retaining small and large fish from multiple year-classes), whereas large mesh gillnets and linetrawls captured larger fish in specific size ranges and few overlapping year-classes. Fish lengths from small mesh gillnets showed several modes between 35 cm and 62 cm throughout the time-series, while those of fish from large mesh gillnets and linetrawls ranged between 62-68 cm and 54-62 cm, respectively. Indices describing the physiological condition of Atlantic Cod varied at both seasonal and annual scales: the liver (hepatosomatic index) and gutted body condition (Fulton's K condition factor) declined over winter and early spring (while the gonadosomatic index increased), then improved over summer after spawning. These trends varied annually over the time-series, but generally declined in 2004-16. Both length and weight-at-age (6^{+} years) have decreased since the early part of each time-series.

INTRODUCTION

The Sentinel Survey of Atlantic Cod (*Gadus morhua*) has been conducted in the Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps since 1995, and currently there are 22 complete years of catch and effort data and biological information. The Sentinel Survey for 2017 was ongoing at the time of the present assessment, and its data will be reviewed in subsequent years.

Sentinel Survey data are collected by trained fish harvesters at various inshore sites along the south coast of Newfoundland (Fig. 1). The main goals of the Sentinel Survey Program include: developing indices of relative abundance (i.e., catch rates) for resource assessments, incorporating knowledge of inshore fish harvesters in the resource assessment process, evaluating inter-annual variability in resource distribution over inshore areas, and collecting information on key biological parameters used in assessments (i.e., fish length, sex, maturity stage, and otoliths to determine fish age).

MATERIAL AND METHODS

Sentinel fishers are requested to fish a control and one experimental site: location of the control site is fixed; and the experimental site can change only within a designated area. For each fishing day, up to half of the fishing gear is deployed at the control site, and the remaining gear is deployed at 1-2 experimental sites at the discretion of Sentinel fishers.

Sentinel Surveys were usually conducted in fall/early winter for 9-12 weeks, except in 1999 (6 weeks), and 2003-04 (8 weeks each). Since 2005, an average of 10 weeks was maintained. In 2016, there were ten sites in Subdiv. 3Ps, predominantly fishing gillnets (5½ inch mesh) in Unit Area 3Psc (Placentia Bay), linetrawls in Unit Areas 3Psb and 3Psa (Fortune Bay and west), and one 3¼ inch mesh gillnet fished one day per week at three sites in Placentia Bay (Fig. 1).

Gillnet crews deployed a maximum of six 50-fathom monofilament nets (5½ inch mesh, rigged 2-3 to a fleet), and up to three fleets per fishing day. Linetrawl crews fished two tubs of baited hooks (approximately 500 hooks per tub) per fishing day. In addition, one small-mesh gillnet (3¼ inch monofilament) tied to one 5½ inch mesh gillnet was fished at selected sites a minimum of one day per week. Data recorded after each fishing set included: set location (latitude, longitude), set start and soak times, marine invertebrates and fish species caught (e.g., bait), marine mammals, seabirds, and several environmental parameters (wind direction and speed, percent cloud cover, tidal conditions). All fish (i.e., Atlantic Cod, bycatch species) caught by gillnets and linetrawls at control and experimental sites were kept separate and sampled on land. Each catch was sorted by species, and total number of individuals and total lengths (cm) by sex were recorded. Atlantic Cod otoliths were sampled using a length-stratified protocol, and up to 100 whole specimens were frozen biweekly and transported to the DFO Northwest Atlantic Fisheries Center laboratory (St. John's, NL) for detailed biological measurements, including total length (cm), gutted weight (g), and liver and gonad weights (g).

INDICES OF PHYSIOLOGICAL CONDITION

Body weight (gutted), liver and gonad weights were used to calculate three indices that reflect the physiological condition of individual Atlantic Cod (Lambert and Dutil 1997; Mello and Rose 2005): Fulton's condition factor (K); Hepatosomatic Index (HSI); and Gonadosomatic Index (GSI);

$$K_i = \left((w_i / l_i^3)\right)$$

$$HSI_i = \left((h_i / w_i) * 100\right)$$

$$GSI_i = \left((g_i / w_i) * 100\right)$$

where w_i is gutted weight (g), l_i is total length (cm), h_i is liver weight (g), and g_i is gonad weight (g) of cod i.

SENTINEL CATCH RATES

Sentinel catch rates for gillnets (3¼ inch and 5½ inch mesh size) and linetrawls were estimated for each fishing day and fishing community as the number of fish per gillnet and number of fish per 1,000 hooks, respectively. Catch weight per unit effort was not estimated, because weigh scales were unavailable to the Sentinel Survey Program.

STANDARDIZED SENTINEL CATCH RATES

As in previous assessments, an age-disaggregated standardized catch rate was estimated for gillnet (5½ inch mesh) and linetrawl series, but data were insufficient to do so for 3¼ inch mesh gillnets.

Sentinel catch-at-age and catch rate from June-November were then standardized using Generalized Linear Models (GLM; McCullagh and Nelder 1989), in order to remove the effects of site selection (age-aggregated model), as well site selection and season (age-disaggregated model). In addition, only gillnets with soak times of 12-32 hours and linetrawls with soak times of 24 hours or less were used in this analysis. Zero cod catches were generated for ages not observed in a set, as sets with effort but no catch were considered valid input to the model. Poisson models with a logarithmic link were fitted with the variables Month and Age as "nested effects": Month was nested within site, and Age was nested within year. Overall model fit was examined using statistical significance of the effects included, and the distribution of residuals.

RESULTS

Sentinel Survey data were gathered from twenty locations since 1995; although the number of enterprises participating in this Program has decreased by 45-50% since 2003 (Table 1). In 1995-2016, the annual number of fishing sets (all gears combined) ranged from 1,937 to 429; with most fishing occurring near Fox Harbour, Little Paradise, Lords Cove, Ramea, Rencronte East, and St. Brides. Note that data collection continues for 2017.

For large mesh (5½ inch) gillnets, the number of fishing sets declined from 400-540 sets per year over 1995-2002, to less than half thereafter (Table 2). Fishing with linetrawls also declined from 300-550 sets/year (except for 1,092 sets in 1995, 181 in 1999) to 130-250 sets/year after 2002. The number of sets conducted with small mesh (3¼ inch) gillnets was less variable: 20-80 tows in most years. Consistent with this reduction of fishing effort using large mesh gillnets, the number of fish measured for length declined by more than ten-fold: from 31,000-45,000 annually in 1995-98 to 1,600-4,000 fish after 2002. Despite a substantial reduction in fishing effort by linetrawl fishers, the number of fish measured annually remained relatively high as compared to gillnets: 36,000-75,000 in 1995-97; 10,000-21,000 during the 2000s; and 4,400-8,500 since 2012. For small mesh gillnets, the number of fish measured was less variable: usually 280-

1,900 annually (except for 2,500 in 1997). The percentage of sets with no catch was low for all gears: 1-4% for large mesh gillnets; <1% for small mesh gillnets; and 1-8% for linetrawls.

SENTINEL CATCH RATES

Mean annual catch rates for gillnets were similar and showed little variability between most fishing enterprises/communities (with a few exceptions), whereas catch rates for linetrawls tended to be more variable among enterprises (Fig. 2). Mean catch rates for large mesh gillnets fluctuated around 14 fish per net, with large variability for enterprises in Little Harbour East, North Harbour, and Monkstown (19-53 fish/net). Mean catch rates for linetrawls were usually 110-112 fish per 1,000 hooks, with the largest ranges from Arnold's Cove, François, and Burgeo (152-174 fish per 1000 hooks). Mean catch rates for small mesh gillnets were mostly 15-26 fish/net, but those from Little Harbour East and North Harbour showed much larger variability (49-78 fish/net).

Temporal trends in mean catch rate (all enterprises/communities combined) were similar for all gears: highest values at the beginning of the time-series; sharp declines after 1997; then values oscillating around or below the overall mean annual catch rate (Fig. 3). Large mesh gillnets yielded the lowest mean annual catch rate of all three gears: declining from 49 fish/net in 1997 to an average of 6 fish/net after 1999. For linetrawls, mean catch rate peaked at 223 fish/1,000 hooks in 1996, fluctuated around 100 fish/1,000 hooks until 2012 (except for 161 fish/1,000 hooks in 2006), then declined to its lowest value of 62 fish/1,000 hooks over 2014-16. Mean catch rate for small mesh gillnets was consistently higher than that of large mesh nets: peaking at 142 fish/net in 1996, then averaging 20 fish/net after 1998 (except for 6 fish/net in 2011).

STANDARDIZED SENTINEL CATCH RATES

No trends were apparent in the distribution of model residuals of standardized catch rates for large mesh gillnets (5½ inch) and linetrawls in 1995-2016; whether by year, month, fishing site, or fishing effort. However, larger confidence Intervals on the distribution of residuals were sometimes observed: during the late-1990s for gillnets; early 2000s for linetrawls; and for some fishing sites (Figs. 4a-b and 5a-b). The nested effects of Month (within Fishing Site) and Age (within Year) in the age-disaggregated model were highly significant ($p < 0.0001$) for both fishing gears (Tables 3 and 4). In addition to the explanatory variable Year, and the nested effect of Month (within Site) in the age-aggregated model was also highly significant for both gears (Tables 5 and 6). These results suggested that overall model parameterizations for standardized Sentinel catch rates were appropriate for gillnets and linetrawls, and no systematic issues regarding model fit were detected.

For large mesh gillnets, standardized annual catch rate-at-age increased from 1995 to 1996, remained relatively high until 1998 (comprised mostly of 5-8 year-old fish), then declined rapidly and remained stable at low levels since 1999 (Fig. 6). Estimates for 2015-16 were the lowest for most age groups. Several year-classes were well-represented over 1995-98, but were replaced by mainly weaker year-classes since then (Fig. 7).The 1997 and 1998 year-classes contributed significantly to the fishery for several years (Rideout et al. 2016). However, these year-classes did not increase the magnitude of Sentinel gillnet catch rates over 2002-06 (i.e., when they would have been in the peak selection range of large mesh gillnets), while being a major contributor to inshore fisheries.

For linetrawls, standardized annual catch rate-at-age was higher at the beginning of the time-series, and dominated by 3-8 year-old fish (Fig. 8). Catch rates increased in 2000-02 due to improved recruitment of 3-4 year-old fish, but those for older fish continued to decline. Several year-classes were well-represented over 1995-98: the 1997 year-class, and especially the 1998

year-class, were consistently caught by Sentinel linetrawls (Fig. 9). In addition, the 1999 year-class also appeared relatively strong as 4-5 year-olds, but was generally below average at older ages. Although these year-classes were followed by several weaker ones, catch rates of the 2004 year-class as 3-5 year-olds in 2007-09 were higher. It should be noted that linetrawl catch rates for 3-10 year-olds increased in 2006; thereby suggesting a year-effect in the data, rather than a change in the Atlantic Cod stock size.

Age-aggregated standardized annual catch rate for large mesh gillnets declined rapidly from 29 fish/net in 1997 to 4 fish/net 1999, then remained stable at low levels (< 4 fish/net) in 1999-2016 (Fig. 10). For linetrawls, catch rate decreased over 1995-99, from 181 to 75 fish per 1000 hooks, remained relatively stable until 2008, then declined to its lowest value (45 fish per 1000 hooks) in this time-series in 2015 (Fig. 11).

BIOLOGICAL INFORMATION

Length

Length frequency distributions of Cod from Sentinel Surveys indicated that large mesh gillnets and linetrawls tended to capture larger fish from specific size ranges with few overlapping cohorts, whereas the small mesh gillnet was the least selective gear: retaining small and large fish from multiple cohorts (Fig. 12). Cod from large mesh gillnets and linetrawls were 19-120 cm (TL) and 16-120 cm, respectively, with modal lengths of 62-68 cm and 54-62 cm, respectively. For small mesh gillnets, fish were 20-116 cm, with smaller modal lengths of 35-62 cm (relative to those from other gears). Furthermore, none of the gear types appeared to track specific cohorts over the time-series.

Indices of physiological condition

All three indices (K, HSI, GSI) that reflect the physiological condition of Cod varied seasonally and annually (Fig. 13). Fulton's K and HSI covaried: showing minimum values in May for females, and April (HSI) and May (K) for males, then peaking in August (HSI) and October (K) for both males and females. The temporal trend in GSI contrasted with those of the other two indices: peaking in May for females and June for males, then reaching minimum values in September for females and October for males. Inter-annual trajectories in K and HSI also covaried: peaking in 2003 for males (K) and 2004 for both males (HSI) and females (K, HSI). Fulton's K and HSI declined afterwards, reaching their lowest values in 2013 (males) and 2014 (females). Female GSI fluctuated without any clear pattern. However, males showed an increasing trend over the time-series: their lowest GSI occurred in 2009, increasing steadily and then peaking in 2011. Male GSI declined in 2012-16, but remained above the levels of previous decades. Confidence intervals for these three indices were usually small.

SENTINEL SURVEY REMOVALS

Total removals (control plus experimental sites, all gears combined) of Cod caught in Subdiv. 3Ps Sentinel Surveys over 2001-16 peaked at 38 t (2001), then declined from 33 t in 2006 to 9.9 t in 2016 (Fig. 14). Fourteen fish species have being recorded as Sentinel bycatch over 2005-16 (Fig. 15): American Plaice (*Hippoglossoides platessoides*) was the most common in gillnets, followed by redfish (*Sebastes* sp.) and Winter Flounder (*Pseudopleuronectes americanus*); while redfish, American Plaice (although decreasing to very low levels since 2012), and wolffish (*Anarhichus* sp.) were the most common on linetrawls. Other species reported infrequently as Sentinel bycatch were: Haddock (*Melanogrammus aeglefinus*), Atlantic Halibut (*Hippoglossus hippoglossus*), Lumpfish (*Cyclopterus lumpus*), Pollock (*Pollachius virens*), skates, Greenland Halibut (*Reinhardtius hippoglossoides*), White Hake (*Urophycis*

tenuis), Witch Flounder (*Glyptocephalus cynoglossus*), and Yellowtail Flounder (*Limanda ferruginea*).

DISCUSSION

As mentioned by Rideout et al. (2016), trends in Subdiv. 3Ps Sentinel catch rates are difficult to interpret, because:

1. Sentinel Cod fisheries operated free from competitive influences while this stock was under moratorium (1995-96);
2. Post-moratorium pressures (i.e., competition from commercial fisheries for fishing sites, local stock depletion, concentration of fishing effort primarily by the Cod gillnet fishery in Placentia Bay) may have negatively impacted the Sentinel fishery; and
3. Inter-annual changes in inshore Cod availability may have negatively affected Sentinel catch rates.

It should be noted that the temporal trend in post-moratorium Sentinel gillnet catch rates was in agreement with other independent data sources:

1. Inshore catch rates from science log books; and
2. High estimates of exploitation in Placentia Bay from tagging studies (Brattey and Healey 2006; Healey et al. 2012).

Furthermore, linetrawl trends presented here tracked the 1997-99 year-classes and, to a lesser extent, 2001-04 year-classes. However, gillnet trends recently indicated no strong contributions from any particular year-class. This result differs from the DFO annual research survey index, which showed that the 2006 year-class was well above average for 3-4 year-old fish, but near average for 5-6 year-olds (Rideout et al. 2016). The 2011 and 2012 year-classes, which appeared strong in the DFO survey, were not yet of an age to be fully selected by gillnets or linetrawls in the 2015-16 Sentinel surveys.

Although the number of enterprises participating in the Sentinel Survey Program has greatly decreased since 2012, this program constitutes an independent source of information that can be readily incorporated in resource assessments of commercial fish stocks (e.g., Subdivision 3Ps Cod). It also engages stakeholders (e.g., inshore fish harvesters) to participate in the shared responsibilities of resource conservation and sustainable exploitation.

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APPENDIX I – TABLES

Table 1. Number of Sentinel Survey sets (all gears) per fishing enterprise/community in Subdivision 3Ps, 1995-2017 (including sets with no catches). Data for 2017 are preliminary.

Community	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arnolds Cove	151	63	69	27	7	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Burgeo	0	46	60	62	28	36	64	45	36	24	28	44	40	36	41	40	40	24	34	32	32	36	16
Fox Harbour	146	87	71	71	36	48	60	60	48	54	54	54	60	60	60	60	60	67	60	58	50	59	20
Francois	181	66	74	68	30	52	35	30	25	10	42	38	28	32	22	27	0	0	0	0	0	0	0
Garden Cove	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	63	69	62	14
Grand Bank	0	0	0	0	0	0	60	59	38	44	43	42	42	46	46	46	27	73	41	38	41	31	0
Harbour Breton	154	39	27	28	32	45	31	53	34	30	33	40	30	38	34	37	36	36	32	40	36	32	11
Lawn	0	57	69	71	36	64	78	80	36	72	68	72	59	54	40	36	6	0	0	0	0	0	0
Little Harbour East	157	48	53	48	10	56	67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Paradise	60	50	51	51	36	49	69	64	42	58	52	56	66	58	63	48	68	40	56	68	75	61	0
Lords Cove	54	48	61	50	36	48	61	82	47	70	69	68	80	80	79	80	77	192	79	80	60	60	30
Monkstown	145	69	72	72	36	57	60	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Harbour	114	73	67	50	19	73	55	42	45	30	55	50	54	43	46	61	52	58	10	0	0	0	0
Placentia	0	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ramea	201	46	96	60	38	88	92	88	46	36	44	44	49	50	48	48	48	48	46	20	0	0	0
Red Harbour	41	36	40	37	20	32	33	57	22	33	36	34	41	34	32	40	37	30	32	25	40	12	24
Rencontre East	174	96	69	74	36	90	71	60	20	32	40	36	36	36	36	36	36	40	40	40	40	40	0
Seal Cove	199	71	44	42	33	58	46	48	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
St. Brides	160	84	74	80	2	52	63	79	59	49	61	64	70	63	49	30	32	68	35	36	25	36	5
Terrenceville	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1937	1020	997	891	435	890	945	907	507	542	625	642	655	630	596	589	519	676	526	500	468	429	120

Table 2. Summary of annual Sentinel Survey number of sets, number of Atlantic Cod measured, and number of sets with no Atlantic Cod by gear type in Subdivision 3Ps, 1995-2017. Data for 2017 are preliminary.

-	Gillnet 3 1/4 in			Gillnet 5 1/2 in			Linetrawl		
Year	No. Sets	No. Fish Measured	Sets with no catch	No. Sets	No. Fish Measured	Sets with no catch	No. Sets	No. Fish Measured	Sets with no catch
1995	2	34	0	762	37776	217	1147	74813	55
1996	10	1421	0	417	40221	12	555	61839	4
1997	22	2544	1	465	44771	6	467	36548	4
1998	29	1829	1	527	31163	20	315	20521	4
1999	6	233	1	234	6329	19	194	9536	13
2000	48	1393	6	424	5578	74	407	19148	25
2001	62	1831	6	497	5720	41	376	18274	28
2002	88	1913	9	499	4958	68	385	21224	13
2003	47	687	3	246	1648	38	214	11612	15
2004	60	1351	6	303	2560	37	179	9301	6
2005	60	723	8	330	2556	51	235	11341	3
2006	61	1067	5	327	2823	46	254	19470	6
2007	63	664	3	360	4027	29	232	13295	5
2008	54	848	1	317	3695	30	259	15979	7
2009	46	674	7	313	2682	68	237	12241	8
2010	52	1000	1	317	2985	50	220	9144	23
2011	49	288	1	265	1578	76	205	9548	7
2012	42	596	8	263	1953	81	182	8527	6
2013	43	589	0	278	2429	71	205	7238	6
2014	43	460	1	272	2241	65	213	6346	9
2015	47	734	1	256	1820	28	213	6333	0
2016	27	533	0	188	1585	61	38	4421	5
2017	14	234	0	55	484	0	27	1327	0

Table 3. Model information and results of fitting age-disaggregated standardized Sentinel catch rates for large mesh gillnets (5 ½ inch) in Subdivision 3Ps, 1995-2016.

Class	Level	Values
Fishing Site	16	61 61.5 63 63.5 64 65 66 66.5 67 68 69 70 71 71.5 73 75
Month	6	6 7 8 9 10 11
Year	22	1995-2016
Age	8	3 4 5 6 7 8 9 10

LR Statistics for Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	56	3440	87.22	<.0001	4884.27	<.0001
Age (Year)	175	3440	109.21	<.0001	19111.1	<.0001

Model Information

Distribution	Poisson
Link Function	Log
Dependent Variable	Catch rate
Offset Variable	Log (Fishing Effort)

Table 4. Model information and results of fitting age-disaggregated standardized Sentinel catch rates for linetrawls in Subdivision 3Ps, 1995-2016.

Class	Level	Values
Fishing Site	16	62 65 68 69 70 71 71.5 73 74 75 76 76.5 76.7 5 77 77.5 78
Month	6	6 7 8 9 10 11
Year	22	1995-2016
Age	8	3 4 5 6 7 8 9 10

LR Statistics for Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	69	2843	28.72	<.0001	1982.01	<.0001
Age (Year)	175	2843	41.5	<.0001	7262.35	<.0001

Model Information

Distribution	Poisson
Link Function	Log
Dependent Variable	Catch rate
Offset Variable	Log (Fishing Effort)

Table 5. Model information and results of fitting age-aggregated standardized Sentinel catch rates for large mesh gillnets (5½ inch) in Subdivision 3Ps, 1995-2016.

Class	Level	Values
Fishing Site	16	61 61.5 63 63.5 64 65 66 66.5 67 68 69 70 71 71.5 73 75
Month	6	6 7 8 9 10 11
Year	22	1995-2016

LR Statistics for Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	56	381	12.87	<.0001	720.74	<.0001
Age (Year)	21	381	53.56	<.0001	1124.82	<.0001

Model Information

Distribution	Poisson
Link Function	Log
Dependent Variable	Catch rate
Offset Variable	Log (Fishing Effort)

Table 6. Model information and results of fitting age-aggregated standardized Sentinel catch rates for linetrawls in Subdivision 3Ps, 1995-2016.

Class	Level	Values
Fishing Site	16	62 65 68 69 70 71 71.5 73 74 75 76 76.5 76.75 77 77.5 78
Month	6	6 7 8 9 10 11
Year	22	1995-2016

LR Statistics for Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
Month (Fishing Site)	69	295	5.95	<.0001	410.4	<.0001
Age (Year)	21	295	8.19	<.0001	172.09	<.0001

Model Information

Distribution	Poisson
Link Function	Log
Dependent Variable	Catch rate
Offset Variable	Log (Fishing Effort)

APPENDIX II – FIGURES

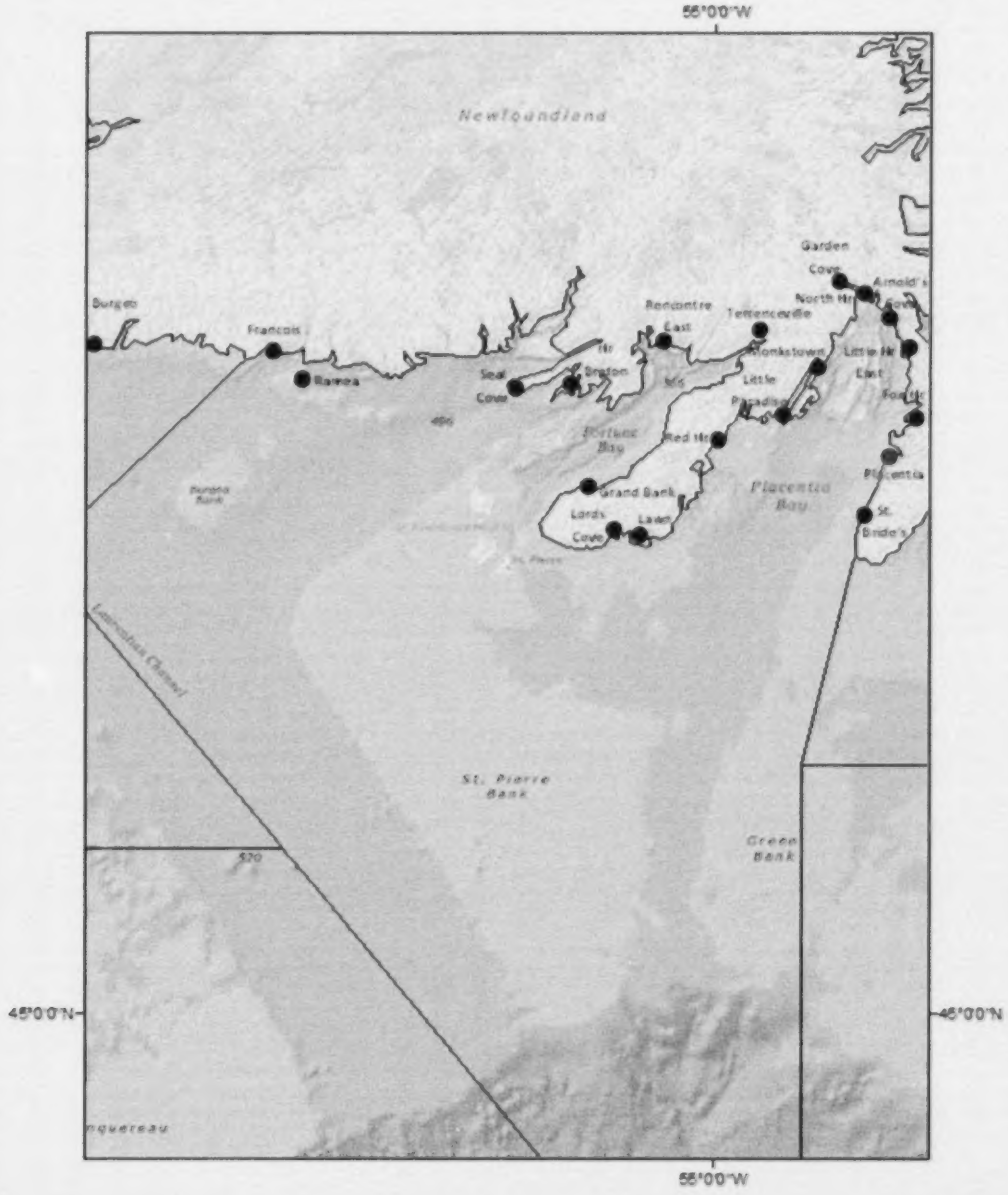

Figure 1. Map of NAFO Subdivision 3Ps indicating the Sentinel Survey communities, 1995-2017.

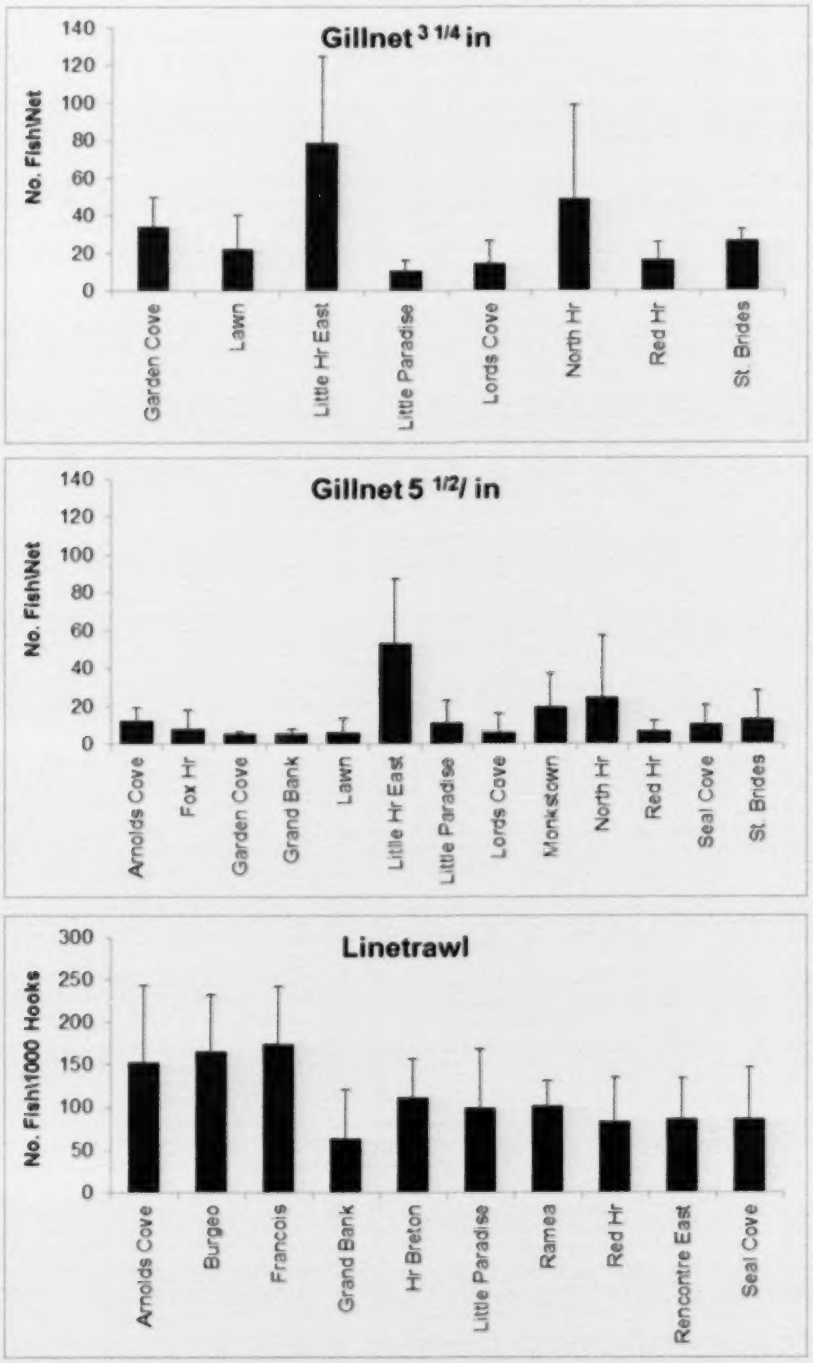

Figure 2. Distribution of mean annual catch rates of Cod from gillnets (number of fish per net) and linetrawls (number of fish per 1,000 hooks), aggregated by fishing communities of Sentinel Surveys in Subdivision 3Ps (control and experimental sites combined), 1995-2017.T-bars = 1 SD. Data for 2017 are preliminary.

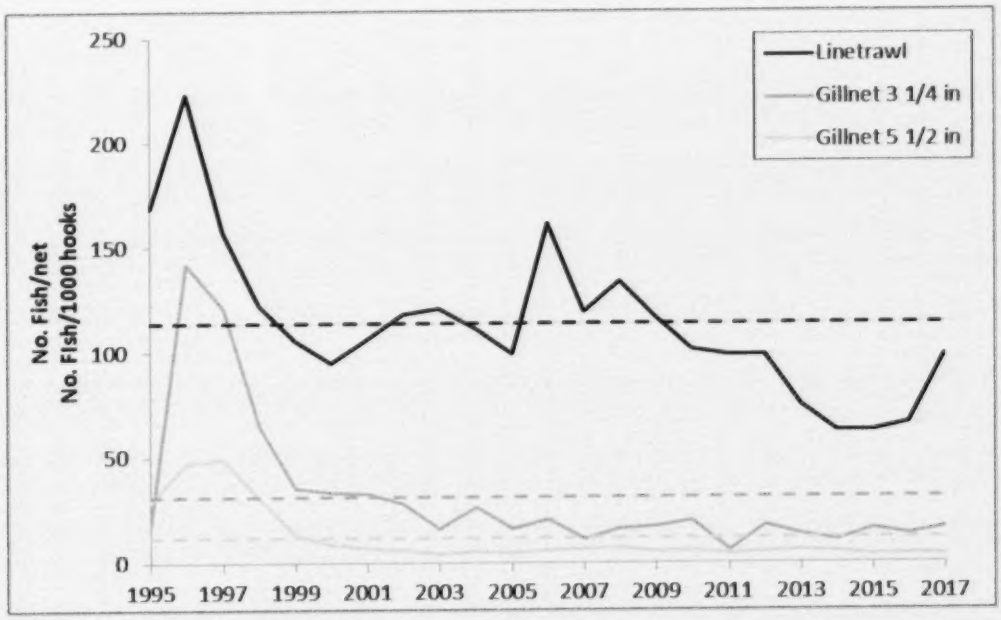

Figure 3. Mean annual catch rates of Cod from gillnets (number of fish per net) and linetrawls (number of fish per 1,000 hooks) from Sentinel Surveys in Subdivision 3Ps (control and experimental sites combined), 1995-2017. Horizontal dashed lines represent the time-series' overall mean for each gear type. Data for 2017 are preliminary

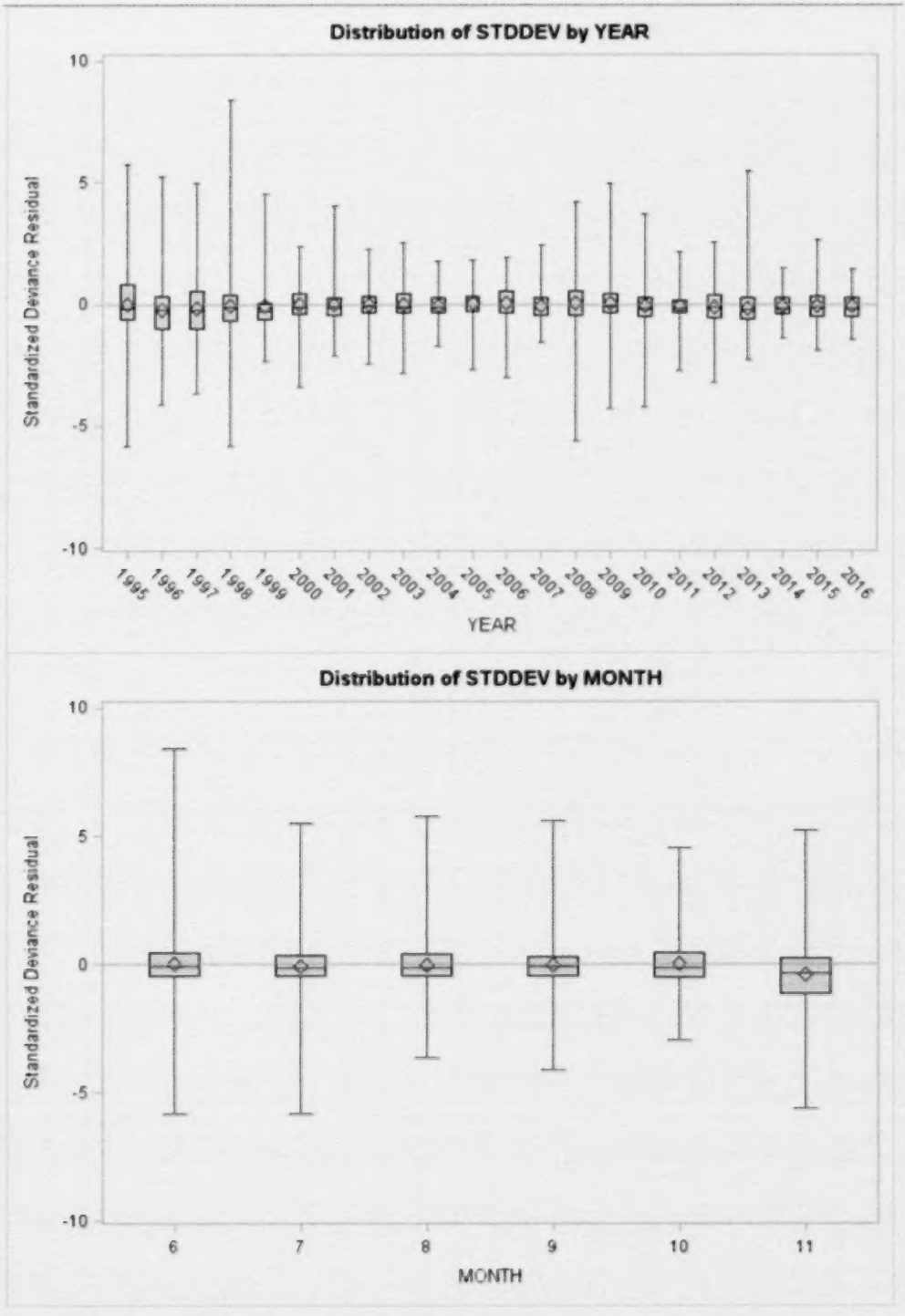

Figure 4a. Deviance residuals (+/-95%CI) from the standardized catch rate model for large mesh gillnets (5 ½ inch) in Subdivision 3Ps, 1995-2016. Panels show residuals plotted by Year, and Month.

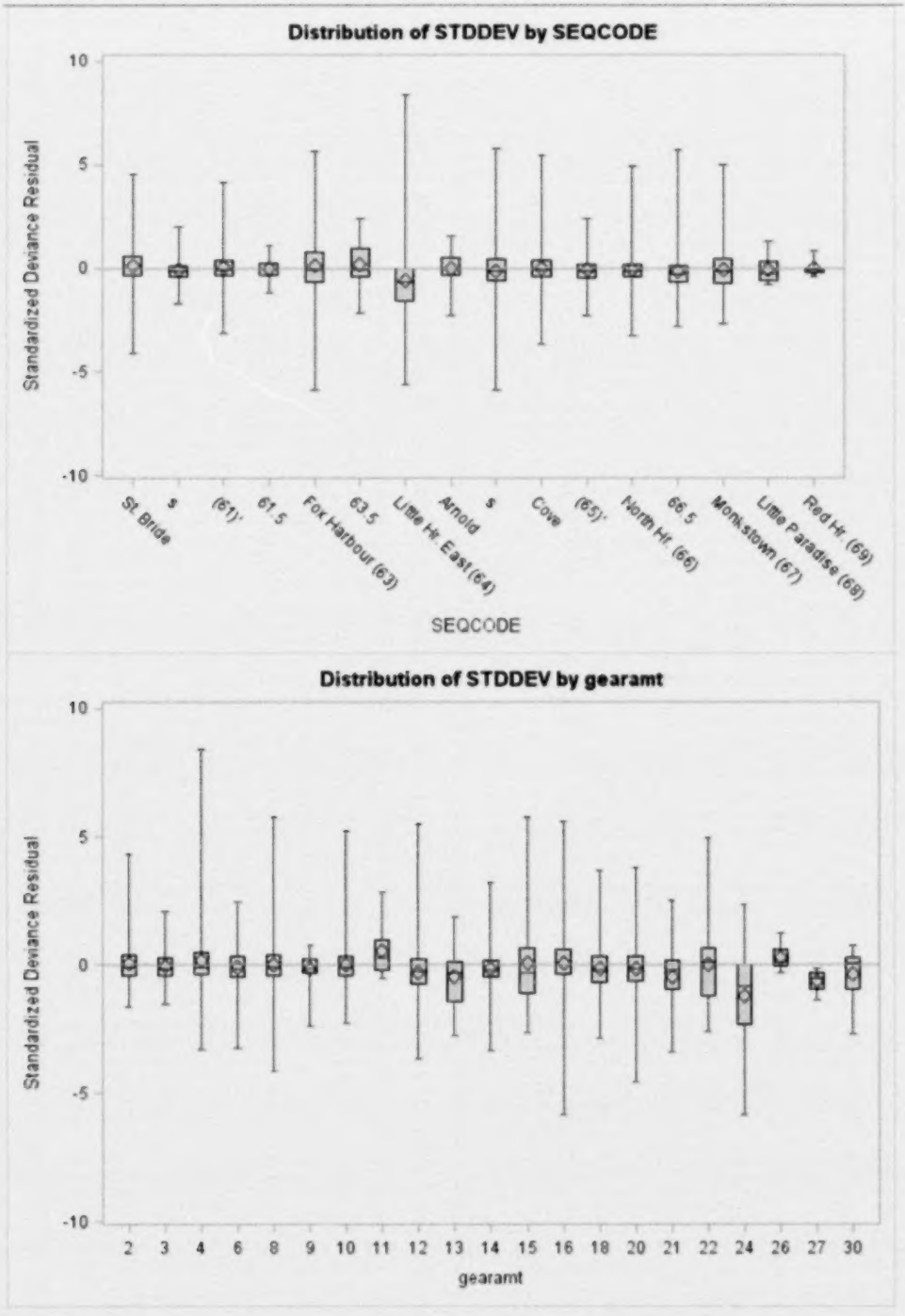

Figure 4b. Deviance residuals (+/-95%CI) from the standardized catch rate model for large mesh gillnets (5 ½ inch) in Subdivision 3Ps, 1995-2016. Panels show residuals plotted by Fishing Site (seqcode), and Fishing Effort (gearamt).

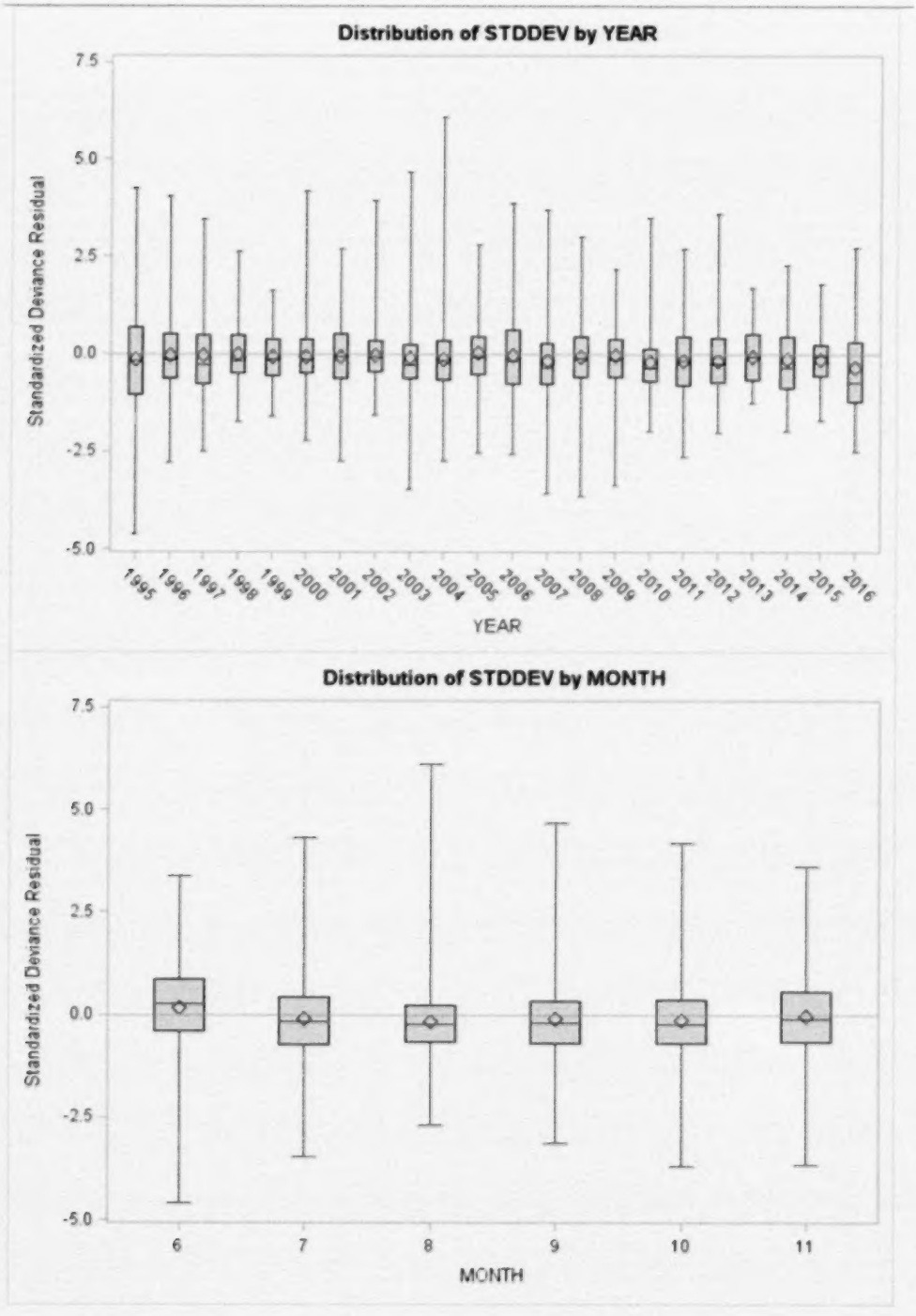

Figure 5a. Deviance residuals (+/-95%CI) from the standardized catch rate model for linetrawls in Subdiv. 3Ps, 1995-2016. Panels show residuals plotted by Year, and Month.

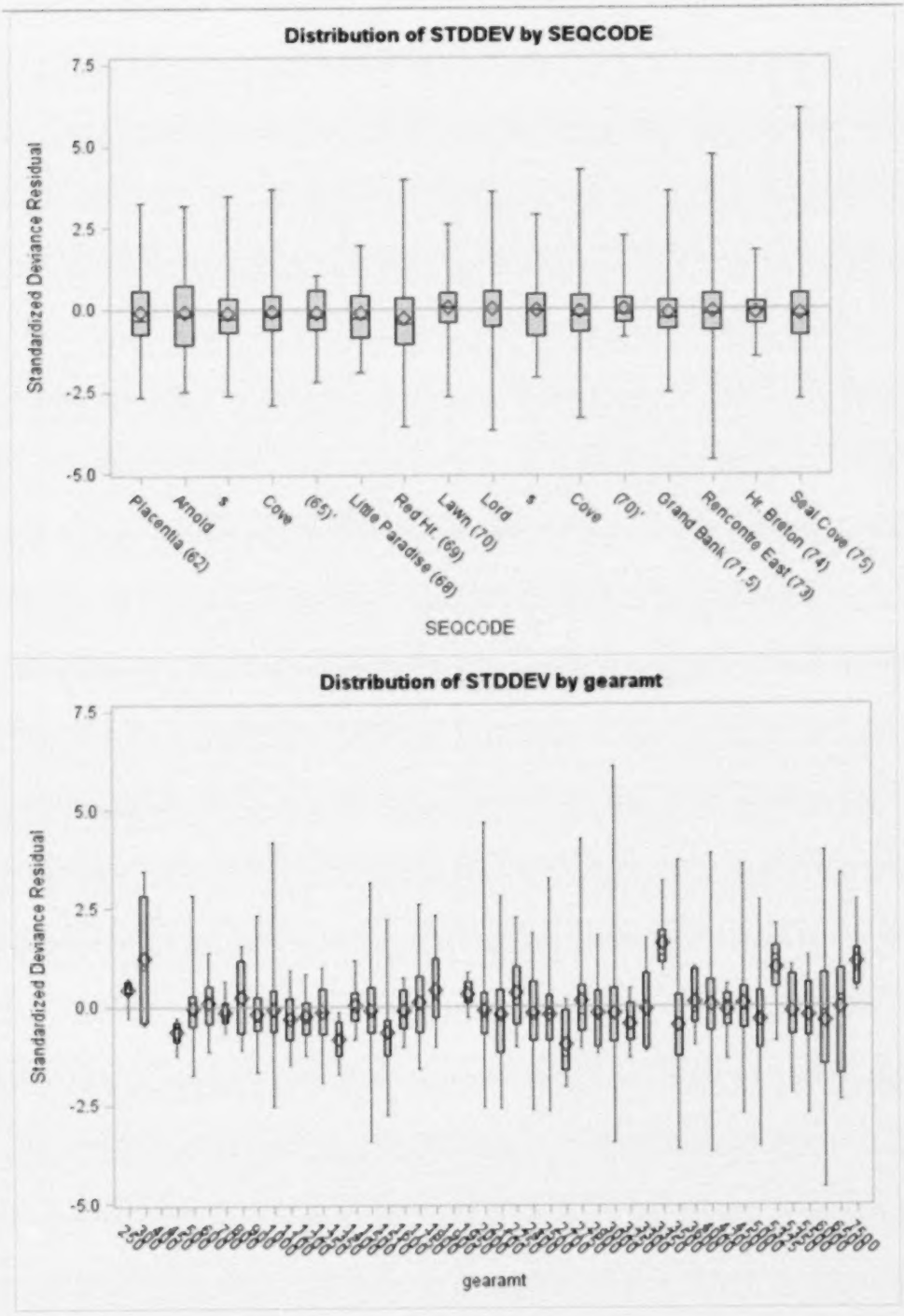

Figure 5b. Deviance residuals (+/-95%CI) from the standardized catch rate model for linetrawls in Subdiv. 3Ps, 1995-2016. Panels show residuals plotted by Fishing Site (seqcode), and Fishing Effort (gearamt).

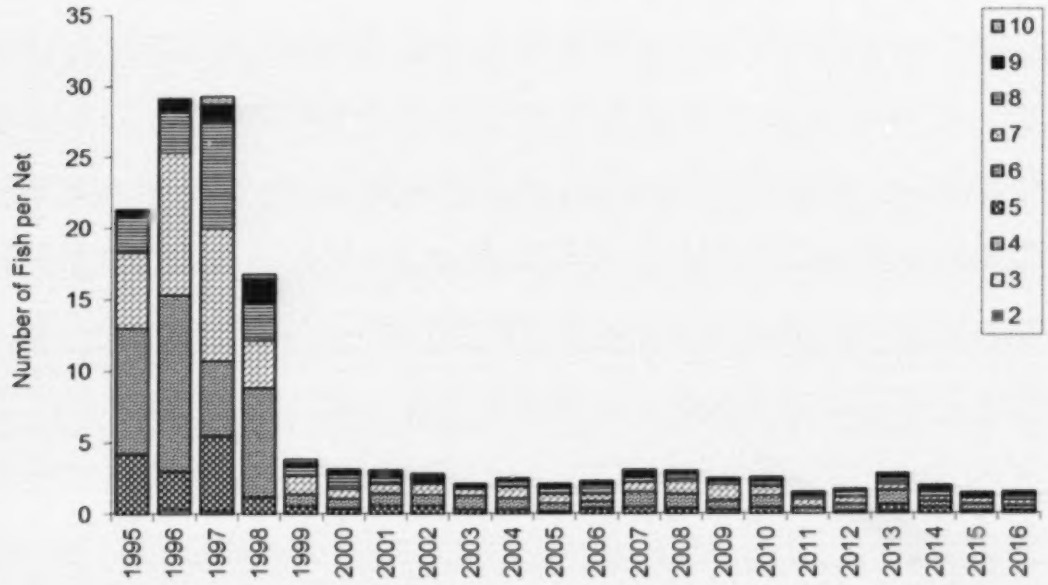

Figure 6. Standardized age-disaggregated catch rates for large mesh gillnets (5½ inch), using data from Sentinel Survey fixed sites in Subdivision 3Ps, 1995-2016.

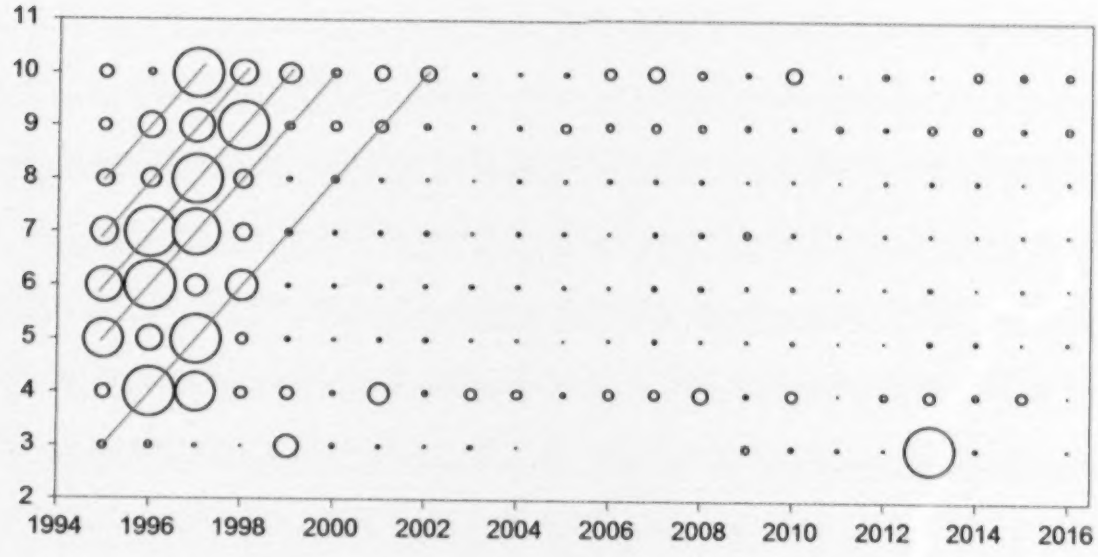

Figure 7. Proportions of Sentinel catch rate-at-age for large mesh gillnets (5½ inch) in Subdivision 3Ps, 1995-2016. Red lines represent different year-classes tracked over time.

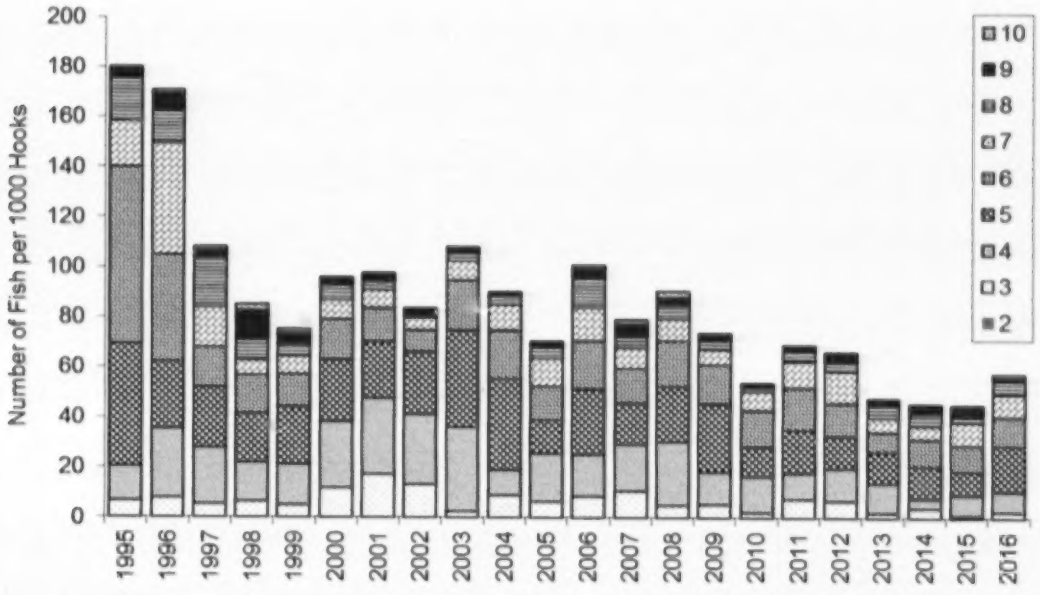

Figure 8. Standardized age-disaggregated catch rates for linetrawls, using data from Sentinel Survey fixed sites in Subdivision 3Ps, 1995-2016.

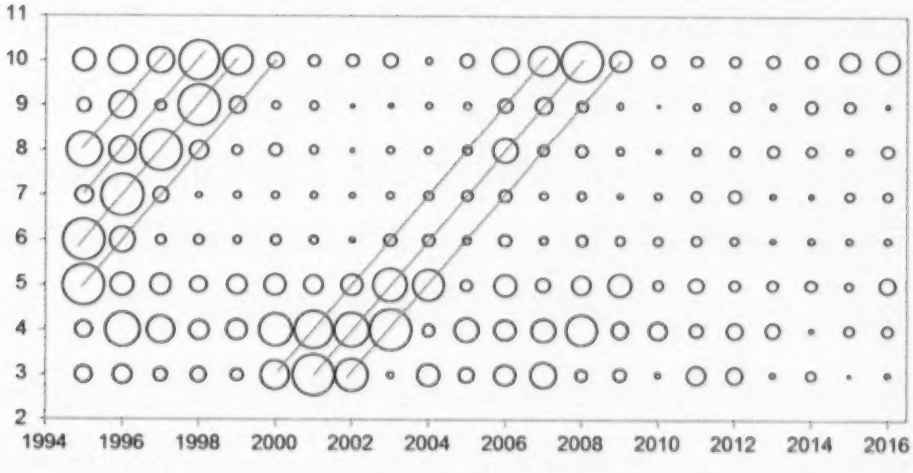

Figure 9. Proportions of Sentinel catch rate-at-age for linetrawls in Subdivision 3Ps, 1995-2016. Red lines represent different year-classes tracked over time.

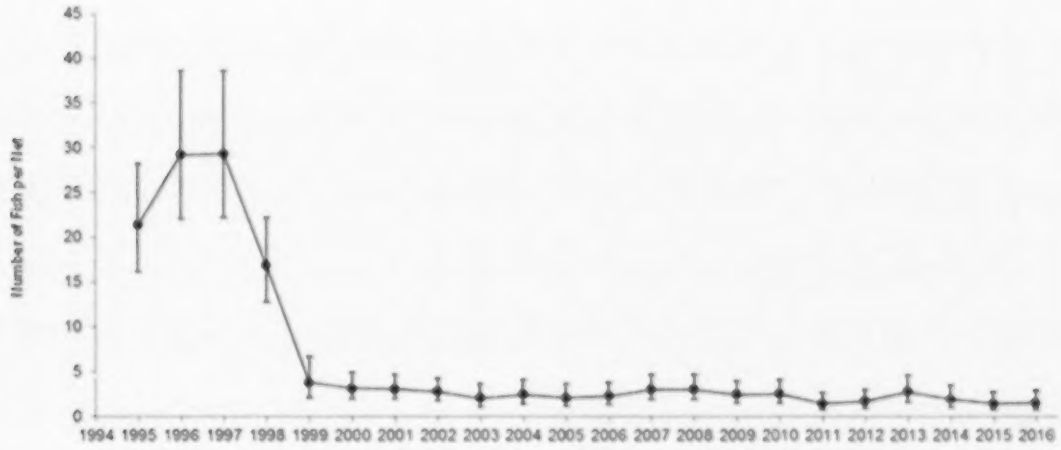

Figure 10. Standardized age-aggregated catch rates for large mesh gillnets (5½ inch) (+/-95% CI), using data from Sentinel Survey fixed sites in Subdivision 3Ps, 1995-2016.

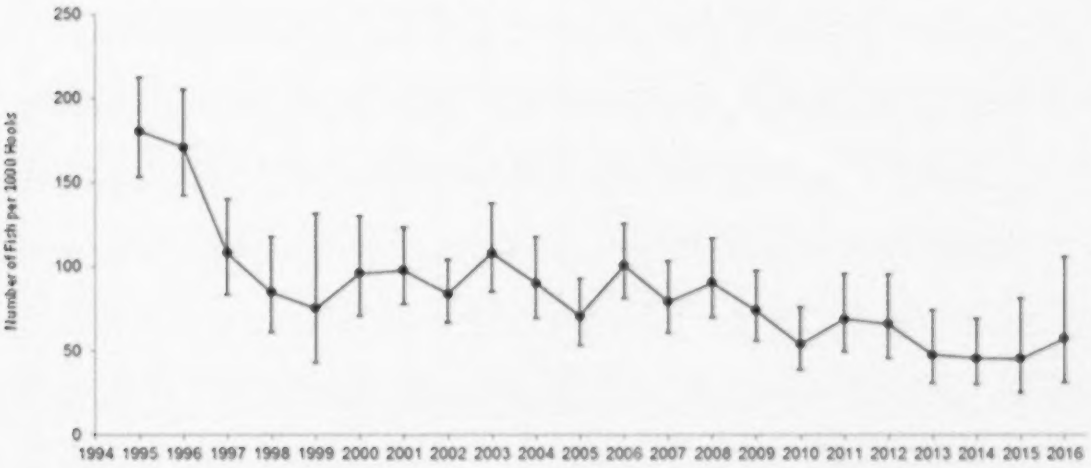

Figure 11. Standardized age-aggregated catch rates for linetrawls (+/-95% CI), using data from Sentinel Survey fixed sites in Subdivision 3Ps, 1995-2016.

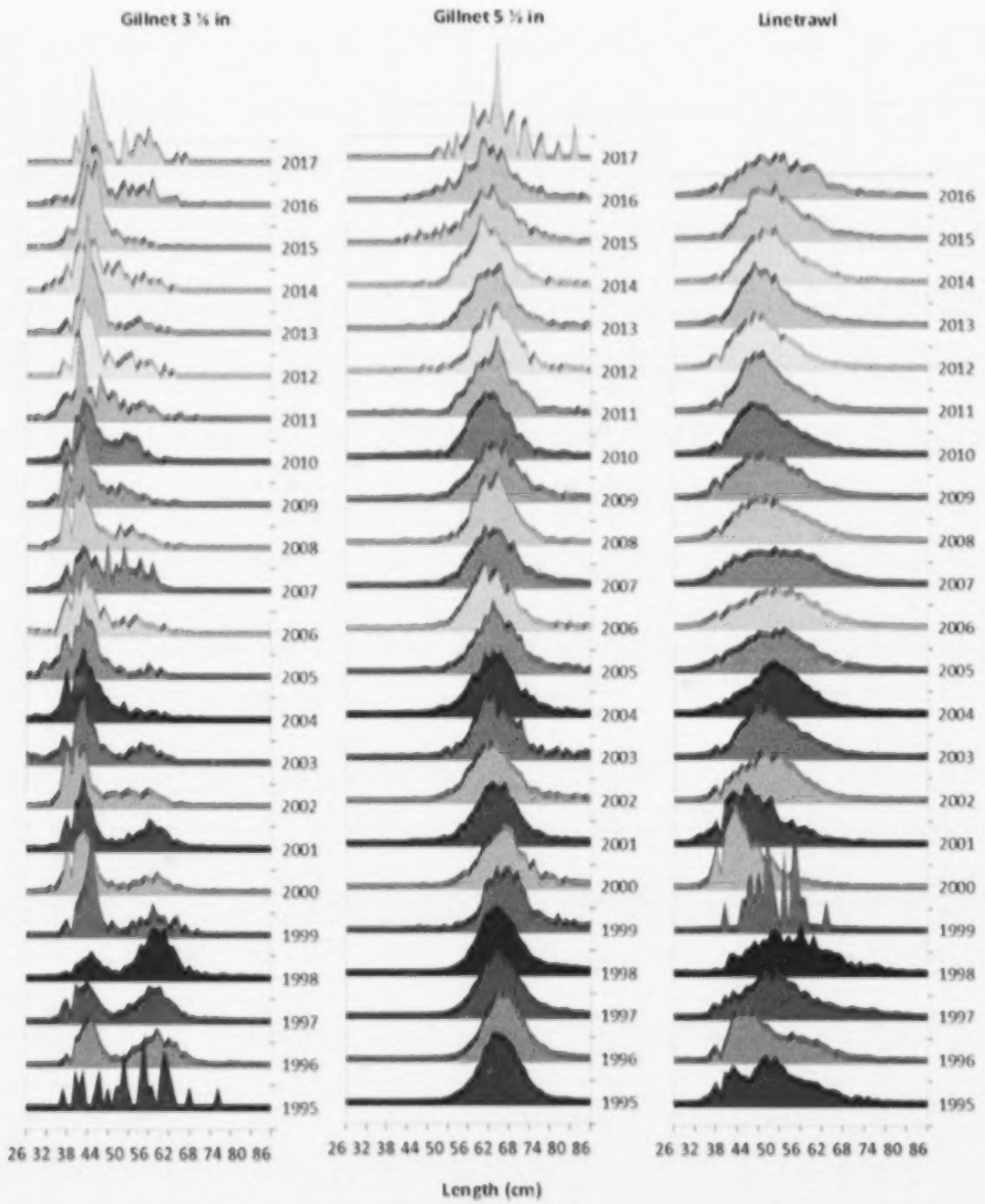

Figure 12. Length distributions (N=7933 fish, number at length scaled to 1) of Cod from Sentinel Surveys in Subdivision 3Ps (control and experimental sites combined), 1995-2017. Data for 2017 are preliminary.

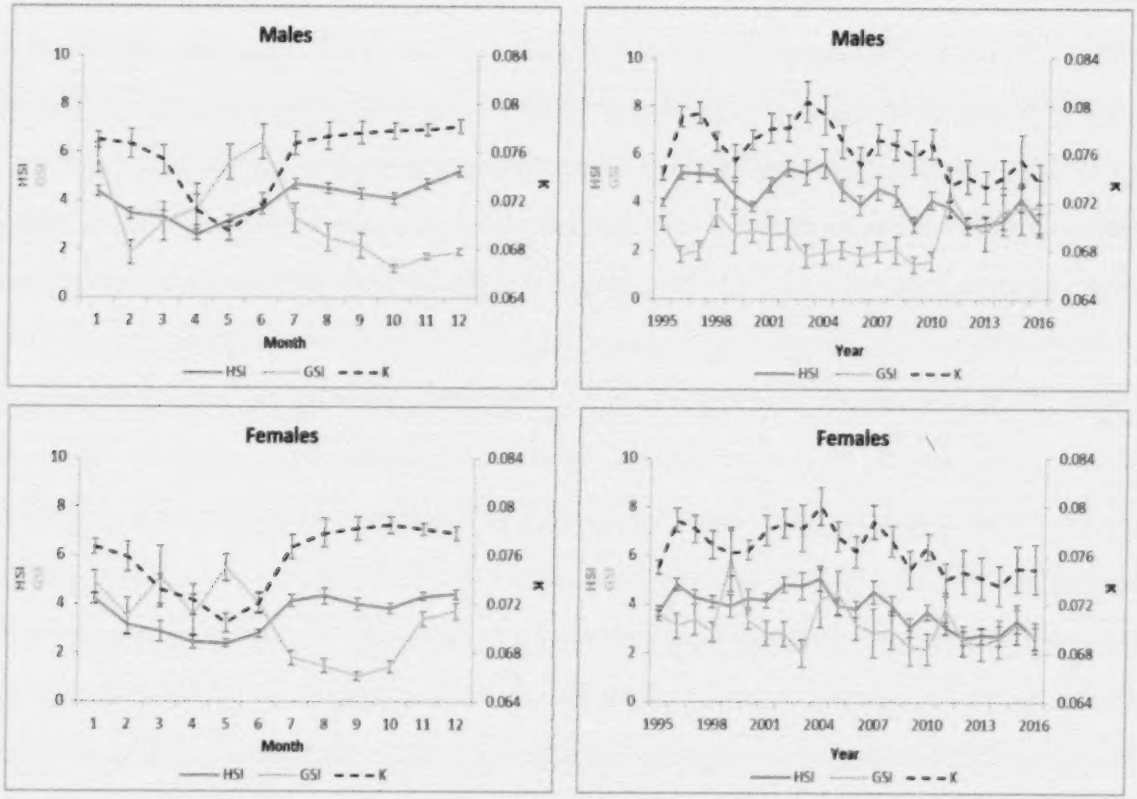

Figure 13. Temporal changes in mean Fulton's K condition factor (N=14,830 fish), mean Hepatosomatic Index (HSI; N=14,480 fish), and mean Gonadosomatic Index (GSI; N=14,649 fish) by sex for Cod (sizes combined) from Sentinel Surveys in Subdivision 3Ps, 1995-2016. T-bars represent +/-95% CI.

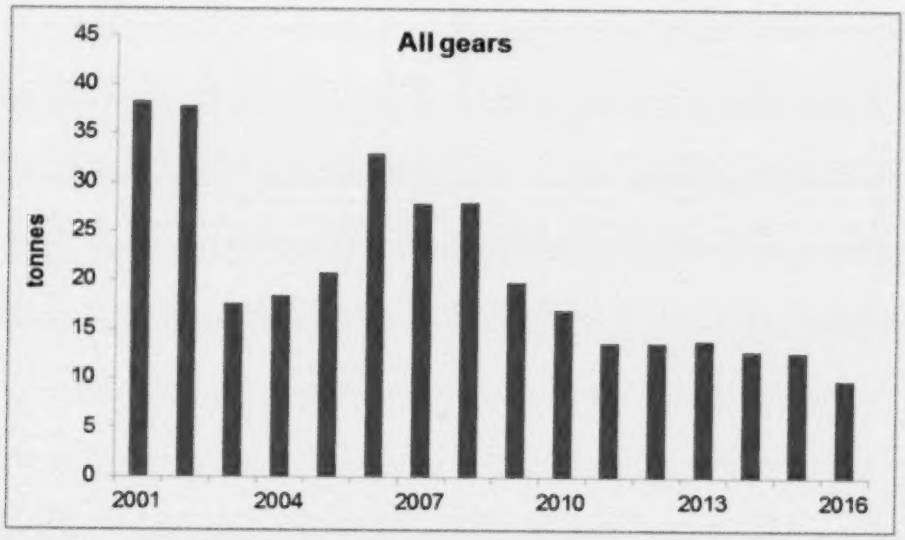

Figure 14. Total annual removals of Atlantic Cod (in tonnes) from Sentinel Surveys (control and experimental sites; all gears combined) in Subdivision 3Ps, 2001-16.

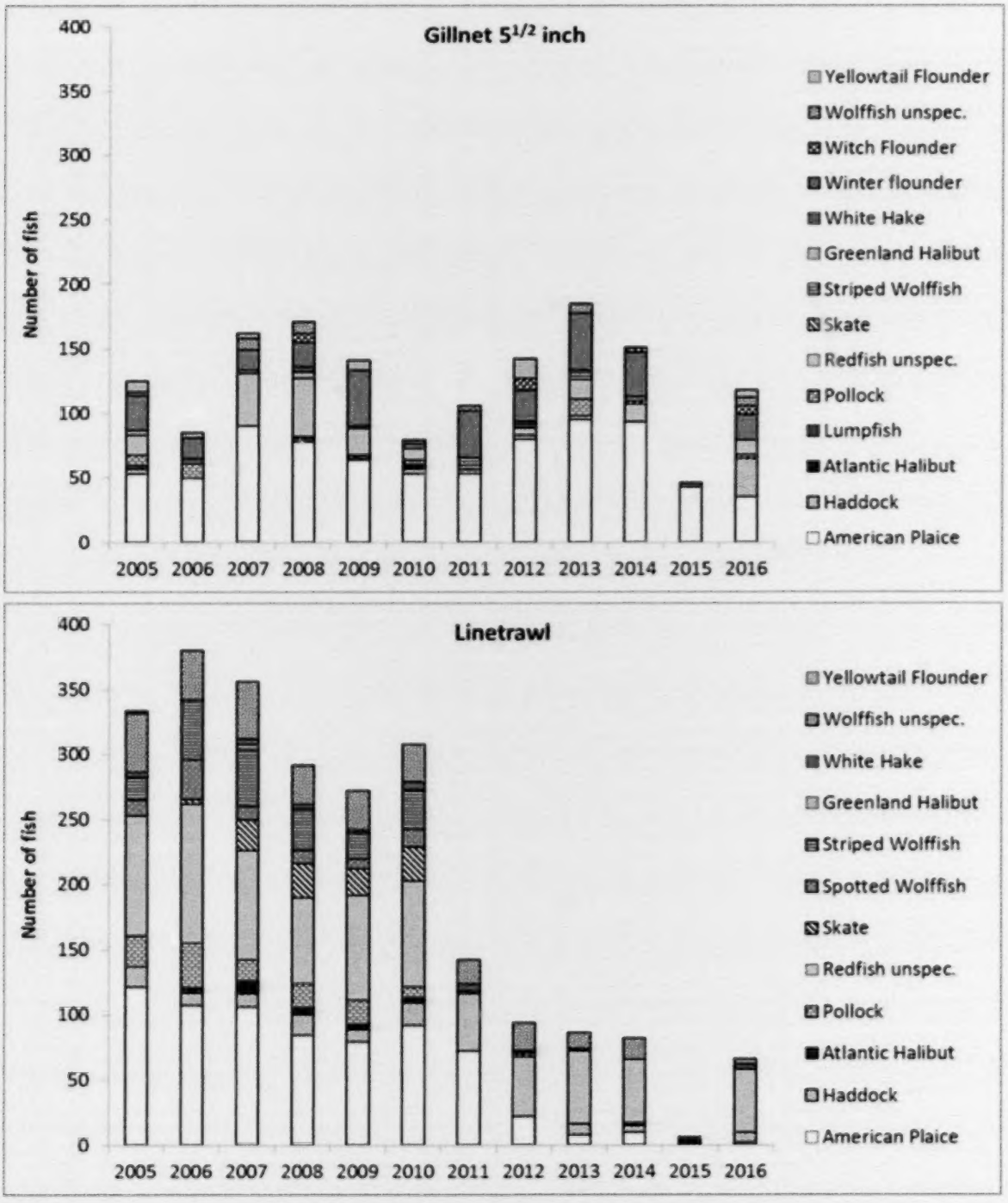

Figure 15. Total annual number of fish per bycatch species from Sentinel Surveys (control and experimental sites; all gears combined) in Subdivision 3Ps, 2005-16.